

Consistent Practices for Characterizing the Detection Limits of Inspection Systems (POD)

Canceled Technology Project (2015 - 2018)



Project Introduction

NASA-STD-5009 requires that successful flaw detection by NDE methods be statistically qualified for use on fracture critical metallic components using Probability of Detection (POD) studies, but does not standardize practices. This task works towards standardizing calculations and record retention with a web-based tool, the NASA POD Standards Library, or NPSL. Best practices for test methods and specimen storage will also be provided with appendices to NASA-STD-5009, which is currently under revision. Additionally, this appendix will describe how POD specimens used to qualify NDE systems will be cataloged, stored and protected from corrosion, damage, or loss.

Background

Flaw detection capability is established for inspection systems on the basis of Probability of Detection (POD). The commonly accepted metric for an adequate inspection system is as follows: for a minimum flaw size which is smaller than the critical defect being sought, there is 90% probability of detection with 95% confidence (90/95 POD). Inspection systems that are incapable of meeting the 90/95 POD requirement at or below the critical defect level for fracture critical components are deemed unsuitable for that inspection.

To provide an efficient and accurate methodology that yields estimates of POD and confidence bounds for Hit-Miss or signal amplitude testing the directed design of experiments for probability of detection (DOEPOD) method has been developed. In DOEPOD, signal amplitudes are reduced to Hit-Miss data by defining a signal threshold. The directed DOEPOD method uses a nonparametric approach for the analysis of inspection data which, unlike other methods, does not rely on simplifying assumptions regarding the general form of a POD function. This differs with other methods that define a POD curve based on a curve fit and does not assume increasing detection with increasing flaw sizes that can often be proven untrue. For a given sample set, the DOEPOD procedure identifies whether the minimum requirement of 90% probability of detection with 95% confidence is demonstrated for a minimum flaw size and for all greater flaw sizes (90/95 POD). These procedures are sequentially executed to minimize the number of samples needed to demonstrate that there is a 90/95 POD lower confidence bound at a given flaw size and that the POD is monotonic for flaw sizes exceeding that 90/95 POD flaw size.

This work provides strong experimental and simulation evidence that a 90/95 POD flaw size will be identified by DOEPOD 95% of the time if it exists, and the procedures will yield a determination that the POD is non-monotonic 97% of the time when it is non-monotonic. Based on this evidence, the DOEPOD methodology may be used to reduce mission risk by quantifiably meeting the requirements of NASA-STD-5009, "Nondestructive Evaluation Requirements for Fracture Critical Metallic Components."



NASA POD Standards Library
(NPSL) logo

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Approach

A total of 860 metal specimens have been produced with a selection of fatigue cracks, fastener hole cracks, lack of weld fusion, and electrical discharge machined (EDM) flaws. The metals used in this study are common throughout aerospace, and include aluminum, titanium, nickel-chromium alloy, and stainless steel. Flat plates and tubes with programmed defects are being examined. These specimens are being examined with x-ray radiography with differing film densities, digital radiography, ultrasound (including phased array), eddy current (including automated methods), florescent penetrant testing (L3 & L4), magnetic particle testing, and visual testing.

Customers

All NASA centers and missions utilizing failure critical components.

Products

The data set generated by this study is vast. Specialized web-based software, termed the NNWG NDE Standards Library (NPSL), is being developed to archive and analyze all data and results. While this web application is being developed and validated to provide analytical support for this study, it will also be expanded upon to provide a centralized and living NDE capability database. Further, it will also provide NDE experts with a standard POD analysis tool for future studies.

Lessons learned during this study will be published in guidance documents for designing statistically adequate POD tests, as new standards, or as appendices to NASA-STD-5009. A comparison to other POD estimation methods will be made to identify validation gaps in methods used for failure critical inspections increasing overall mission success. (NASA/TM-2014-218183).

Project Manager

Charles Nichols

Organizational Responsibility

Responsible Mission Directorate:

Office of Safety and Mission Assurance (OSMA)

Lead Center / Facility:

White Sands Test Facility (WSTF)

Responsible Program:

Nondestructive Evaluation Program

Project Management

Program Director:

Terrence W Wilcutt

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Accomplishments

- 100 percent of the flawed samples have been manufactured and delivered for testing.
- Publication of DOEPOD methodology. 70% of the specimens have been tested.
- *DOEPOD v.1.2* and manual available.
- Familiarization training on LaRC/GSFC file structure and *DOEPOD* complete.
- Electronic/hard copy data consolidated
- NPSL software requirements agreed to including cataloging and searching capabilities.
- POD literature review and draft 'Best Practices' completed.
- Review outsourced to POD experts (Brown, Aldrin, Volovoi) and NESC NDE TDT statused.

Anticipated Benefits

Although required for fracture critical metallic components per NASA-STD-5009 and used throughout the Agency to qualify inspection capabilities, the conduct of and tools for Probability of Detection (POD) analyses are not standardized. Software used for POD analyses are not validated meeting Agency standards spelled out in NPR 7150.2B. Because of this and lack of configuration control, the results of analyses completed today on the same data set do not arrive at the same results. Further, no system exists for cataloging POD data nor specimens used across the agency to provide tracability and reduce needless rework. Specimens used in POD studies are costly to produce and many have been damaged through mishandling and improper storage. This project applies NASA's common 90/95 POD methods

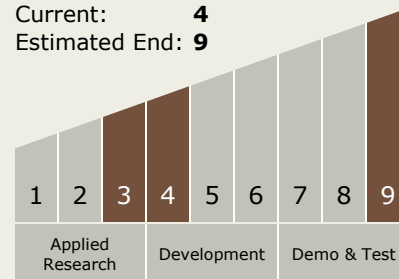
Project Management (cont.)

Co-Investigators:

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John C Aldrin
Laura J Sanchez Lozada
Jill E George
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Technology Maturity (TRL)

Start: 3
Current: 4
Estimated End: 9



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
 - └ TX12.4 Manufacturing
 - └ TX12.4.5 Nondestructive Evaluation and Sensors

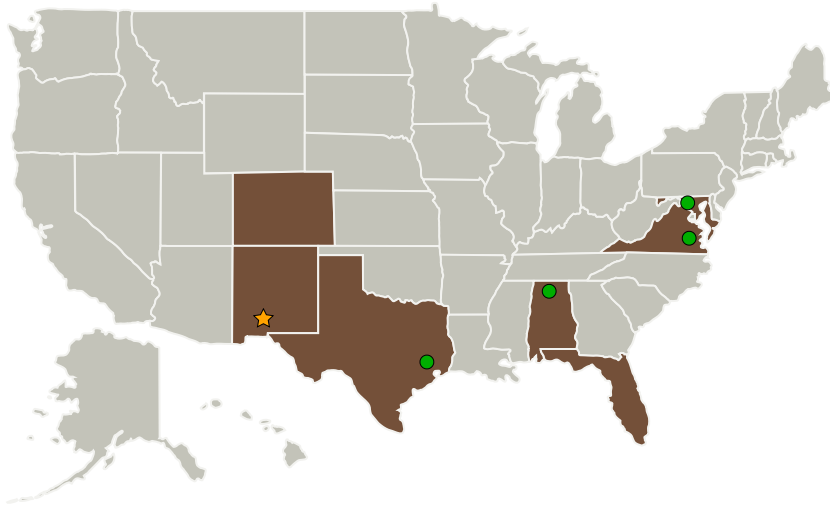
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and (1) drafts an appendix to the NASA-STD-5009, focusing on best practices for performing POD analyses and storing NDT specimens. (2) An online database, meeting Agency backup and software requirements, will be produced to catalog POD reports, log data, and track specimen locations. (3) The online tool will later be enhanced, perhaps in collaboration with AFRL, with common analysis routines used in POD studies. This software will be validated meeting the stringent standards set forth in NPR 7150.2B and will be configuration controlled.

Primary U.S. Work Locations and Key Partners



Target Destination

Foundational Knowledge

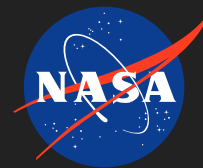
Supported Mission

Type

Planned Mission (Pull)

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Organizations Performing Work	Role	Type	Location
★ White Sands Test Facility(WSTF)	Lead Organization	NASA Facility	Las Cruces, New Mexico
● Goddard Space Flight Center(GSFC)	Supporting Organization	NASA Center	Greenbelt, Maryland
● Johnson Space Center(JSC)	Supporting Organization	NASA Center	Houston, Texas
● Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia
● Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations	
Alabama	Colorado
Florida	Maryland
New Mexico	Texas
Virginia	

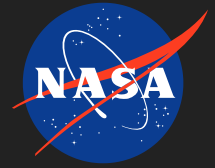
Project Transitions

-  **October 2015:** Project Start
-  **September 2018:** Project canceled because budget cuts, funding reallocation, or insufficient funding
Rationale: Project canceled because budget cuts, funding reallocation, or insufficient funding
-  **September 2018:** Closed out

Closeout Summary: Draft appendices to NASA-STD-5009 was completed to identify the overall POD process for NASA partner organizations. Specimen storage best practices were also provided, addressing a longstanding shortcoming with costly NASA physical reference standards. An online database was generated (TRL-2 to TRL-8), providing a single location for obtaining a listing of all existing physical reference standards - potentially saving the agency over one million dollars in the first 5 years. Center tribalism must be overcome, and agency-wide funding provided, to populate and sustain the database bringing it to full adoption and TRL-9. Further, additional support and push are required at the top level to fully implement all NASA-STD-5009 appendices.

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Images

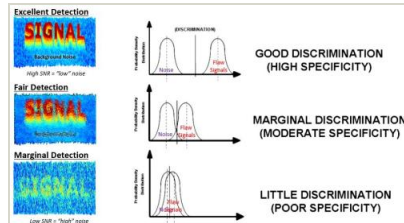


NASA POD Standards Library (NPSL) logo

NASA POD Standards Library

(NPSL) logo

(<https://techport.nasa.gov/image/16568>)



POD evaluates inspection effectiveness

Probability of Detection evaluates the effectiveness of inspection techniques and inspectors

(<https://techport.nasa.gov/image/20720>)

Links

Binomial Test Method for Determining Probability of Detection Capability for Fracture Critical Applications
(<http://ntrs.nasa.gov/search.jsp?R=20110015149>)

Directed Design of Experiments for Validating Probability of Detection Capability of NDE Systems (DOEPOD), NASA TM 2015-218696

(<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013987.pdf>)

Interrelationships Between Probability of Detection Methodologies, NASA/TM-2014-218183

(<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140005337.pdf>)

NASA DOEPOD NDE Capabilities Data Book, NASA TM 2015-218770

(<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150013943.pdf>)

TechPort Public Release Document

(<https://daa.jsc.nasa.gov/showrecord.cfm?controlno=35822>)

US Patent 8108178, Directed Design of Experiments for Validating Probability of Detection Capability of a Testing System

(<http://www.anypatents.com/patents/US8108178>)

Project Website:

<https://sma.nasa.gov/sma-disciplines/nondestructive-evaluation>